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INTERNATIONAL APPLICATION PUBLISHED UNDER :

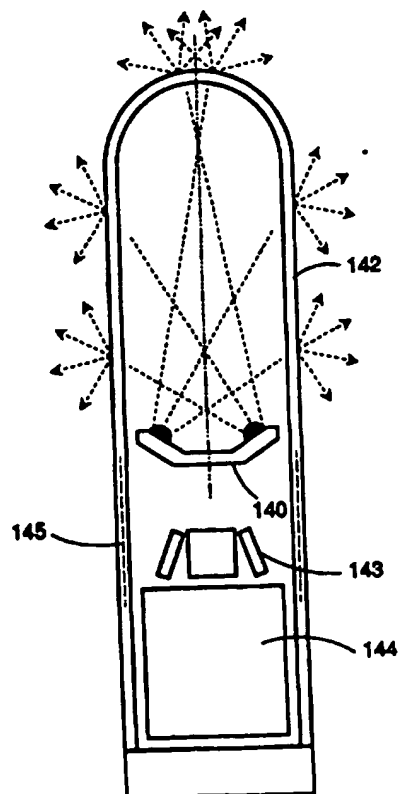
WO 9608090A1

(51) International Patent Classification 6 : <b>H04B 10/10</b>		A1	(11) International Publication Number: <b>WO 96/08090</b>
			(43) International Publication Date: 14 March 1996 (14.03.96)
(21) International Application Number: <b>PCT/EP94/02940</b>		(81) Designated States: BR, CA, CN, CZ, HU, JP, KR, PL, RU, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).	
(22) International Filing Date: 3 September 1994 (03.09.94)			
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(54) Title: OPTICAL TRANSMITTER AND TRANSCEIVER MODULE FOR WIRELESS DATA TRANSMISSION

## (57) Abstract

Disclosed are optical transmitter and transceiver modules for data communication. Such a transceiver module comprises an array of light emitting diodes mounted on a mounting base (140) being arranged in a regular and symmetrical manner in a dome-shaped housing (142). This housing (142) comprises diffusor means for source enlargement. In addition to the transmitter part consisting of said diodes, the transceiver module comprises a receiver. The receiver has four photodiodes (143) arranged below the mounting base (140). These photodiodes are tilted and face in different directions to receive light from all around the module. The photodiodes are protected by a thin wire mesh (145) which serves as Faraday cage to reduce electro magnetic interference. A substrate (144) for electronic circuitry in SMD-Technology is situated underneath the photodiodes (143).



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**DESCRIPTION**

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**Optical Transmitter and Transceiver Module  
for Wireless Data Transmission****TECHNICAL FIELD**

10 The present invention concerns transmitter and transceiver modules for the optical data transmission. These modules are in particular suited for the use in infra-red data transmission systems.

**BACKGROUND OF THE INVENTION**

15 With the rapidly increasing number of workstations and personal computers (e.g. desktop or handheld ones) in all areas of business, administration, and fabrication, there is also an increasing demand for flexible and simple interconnection of these systems. There is a similar need as far as the hook-up and interconnection of peripheral devices, such as keyboards,  
20 computer mice, printers, plotters, scanners, displays etc., is concerned. The use of electrical wire networks and cables becomes a problem in particular with increasing density of systems and peripheral devices and in the many cases where the location of systems, or the configuration of subsystems, must be changed frequently. It is therefore desirable to use wireless  
25 communication systems for interconnecting such devices and systems to eliminate the requirement of electrical cable networks.

In particular the use of optical signals for exchanging information between systems and remote devices received increased interest during recent  
30 years. The advantage of such wireless optical communications systems is the elimination of most of the conventional wiring. With respect to radio frequency (RF) wireless transmission, optical infrared (IR) wireless transmission has the advantages that no communication regulations apply

1 and no PTT or FCC license is required. Additionally, no disturbance by  
electro-magnetic interference and no interference from other RF channels  
can occur, and the radiation is confined to a room so that better data  
security is guaranteed than with RF systems. There is thus no interference  
5 with similar systems operating next door and a higher degree of data  
security is afforded than radio-frequency transmission can offer. In contrast  
to radio-frequency antennae, the dimensions of light emitting diodes (LED)  
and photodiodes are usually smaller, which is of particular interest when  
designing portable computers.

10

The optical signals in such systems might directly propagate to the optical  
receiver of the receiving system or they might indirectly reach the receivers  
after changes of the direction of propagation due to processes like  
reflections or scattering at surfaces. Today, the former case is realized in  
15 docking stations for portable computers where the data transfer takes place  
between an optical transmitter and a receiver which are properly aligned  
and close together at a distance on the scale of cm. The latter case is  
typical for applications in an office environment in which undisturbed direct  
transmission of optical signals between transmitters and receivers several  
20 meters away from each other is impractical or even impossible due to  
unavoidable perturbations of the direct path. One known approach to  
achieve a high degree of flexibility is to radiate optical signals from the  
transmitting system to the ceiling of an office where they are reflected or  
diffusely scattered. Thus, the radiation is distributed over a certain zone in  
25 the surroundings of the transmitter. The distribution of the light signals  
spreading from the ceiling depends on many details which are characteristic  
for the particular environment under consideration. However, essential in  
this context is mainly that the transmission range, i. e. the distance between  
transmitting system and receiving system, is limited to some final value,  
30 hereafter called the transmission range, since the energy flux of the  
transmitted radiation decreases with increasing distance of propagation and  
the receiver sensitivity is limited due to a final signal-to-noise ratio. Typical  
known systems, operating at levels of optical power which are limited by the

1 performance of the light sources and safety requirements for light exposure,  
have demonstrated transmission ranges of several meters for data rates of  
1 Mbps.

5 Crucial parameters of a wireless optical communication system are the  
achievable data rate and the distance between the systems exchanging  
data. In an office environment, it can be necessary to communicate data  
over distances exceeding the transmission range of a conventional optical  
transmitter.

10

There are several disadvantages of today's wireless optical data  
transmission systems. First, the transmission range is not suited for use in  
environments such as for example large office rooms and conference rooms  
and the radiation characteristic and range is usually not uniform, thus  
15 requiring precise alignment of transmitter and receiver.

In addition, one has to take into account that in most environments there is  
unavoidable ambient light, such as daylight or light from lamps, which  
always reaches the optical detectors, unless the system is restricted for the  
20 use in a completely dark environment. Unavoidable ambient light can lead  
to time-dependent signals, for example AC signals from lamps, and is an  
important, in many practical cases the dominant source of noise in the  
optical receiver. Thus, ambient light influences the signal-to-noise ratio of  
the receiver and, therefore, affects the transmission range. The appearance  
25 of unavoidable light is mostly statistical and often difficult to control and its  
intensity can drastically change, as it is apparent for sunlight or lamps being  
switched on and off. A further realistic effect which statistically affects the  
signal-to-noise ratio and thus the transmission range is the occurrence of  
optical path obstructions influencing the receiver signal.

30

A first approach to get round these problems would be to increase the  
output power of the transmitter module. This has proven to be impractical  
for several reasons. The power consumption of such transmitter modules

1 would be way to high for use in portable systems such as for example in  
notebook computers or palmtop computers. However, the most important  
issue facing the development of optical wireless systems is optical safety. It  
is anticipated that optical radiation can present a hazard to the eye and to  
5 the skin if the exposure is high enough. The degree of hazard depends on a  
number of factors, including the exposure level (energy or power), exposure  
time and wavelength.

In the article "Optical Wireless: New Enabling Transmitter Technologies", P.P  
10 Smyth et al., IEEE International Conference on Communications '93, May  
23-26, 1993, Geneva, Switzerland, Technical Program, Conference Record,  
Volume 1/3, pp. 562 - 566, changes to existing eye safety standards as well  
as a new form of transmitter technology are discussed. This new form of  
transmitter technology is based on the idea to enlarge the area of the  
15 optical source in order to reduce the danger of retinal damage. In this  
article it is proposed to use a computer generated phase hologram for  
example, to obtain multiple beams for beam shaping out of a single laser  
diode source.

20 This approach is a first step in the right direction, but the problem of  
insufficient transmission range and sufficient eye-safety has not yet been  
addressed and solved.

## 25 SUMMARY OF THE INVENTION

It is an object of the present invention to provide for an improved optical  
transmitter module.

30 It is a further object of the present invention to provide for an optical  
transmitter module of small size and with optimum radiation pattern.

1 It is another object of the present invention to provide for an optical transmitter module which satisfies safety standards (IEC 825-1).

It is another object of the present invention to provide for an optical  
5 transmitter module with switchable radiation pattern.

The above objects have been accomplished by provision of optical transmitter modules as hereinafter claimed.

10

#### DESCRIPTION OF THE DRAWINGS AND NOTATIONS USED

The invention is described in detail below with reference to the following  
15 drawings:

**FIG. 1** shows a schematic cross-section of an optical transmitter module in accordance with the present invention.

20 **FIG. 2** shows three different regular and symmetrical configurations of light emitting diodes.

**FIG. 3** shows a schematic cross-section of an optical transmitter module in accordance with the present invention.

25

**FIG. 4** shows a schematic cross-section of an optical transmitter module in accordance with the present invention.

**FIG. 5** shows a schematic cross-section of an optical transmitter  
30 module in accordance with the present invention.

**FIG. 6A** is a cross-sectional view of a dome-shaped housing.

- 1     **FIG. 6B**     is a cross-sectional view of a dome-shaped housing.
- FIG. 7**     shows a schematic cross-section of an optical transmitter module in accordance with the present invention.
- 5     **FIG. 8**     is a schematic top-view of an optical transmitter module in accordance with the present invention
- FIG. 9**     is a schematic top-view of an optical transmitter module in accordance with the present invention.
- 10     **FIG. 10**     shows a schematic cross-section of an optical transmitter module in accordance with the present invention.
- FIG. 11**     shows a schematic cross-section of an optical transmitter module in accordance with the present invention.
- 15     **FIG. 12**     shows a schematic cross-section of an optical transmitter module with switchable radiation pattern in accordance with the present invention.
- 20     **FIG. 13A**     is a schematic top-view of the optical transmitter module with switchable radiation pattern illustrated in Figure 12.
- FIG. 13B**     is a schematic top-view of the optical transmitter module with switchable radiation pattern illustrated in Figure 12.
- 25     **FIG. 13C**     is a schematic top-view of the optical transmitter module with switchable radiation pattern illustrated in Figure 12.
- 30     **FIG. 14**     shows a schematic cross-section of an optical transceiver module in accordance with the present invention.



1     **FIG. 15A**     shows a schematic cross-section of an optical transceiver module in accordance with the present invention.

5     **FIG. 15B**     is a schematic top-view of the receiver part of the optical transceiver module illustrated in Figure 15A.

**FIG. 16**     shows a schematic cross-section of an optical transceiver module in accordance with the present invention.

10    **FIG. 17A**     shows a schematic cross-section of an optical transmitter module with switchable radiation pattern in accordance with the present invention.

15    **FIG. 17B**     is a schematic top-view of the housing and reflector ring of the optical transceiver module illustrated in Figure 17A.

**FIG. 18A**     shows a schematic cross-section of an optical transmitter module with switchable radiation pattern in accordance with the present invention.

20    **FIG. 18B**     is a schematic top-view of the housing and reflector ring of the optical transceiver module illustrated in Figure 18A.

25    **FIG. 19A**     shows a schematic view of a fixture for mounting an optical transmitter/transceiver module with switchable radiation pattern in accordance with the present invention.

**FIG. 19B**     is a schematic view of the fixture of Figure 19A in a tilted position.

30    **FIG. 20**     shows a schematic cross-section of an optical transmitter module with switchable radiation pattern in accordance with the present invention.

1 **FIG. 21A** shows a notebook computer with an optical transmitter or transceiver module being attached to it.

**FIG. 21B** shows a notebook computer with an integrated optical transmitter or transceiver module.

**FIG. 22** is a schematic block diagram of the analog frontend of a transceiver in accordance with the present invention.

## 10 GENERAL DESCRIPTION

In view of the above it is highly desirable for wireless optical transmitter modules to meet the following criteria:

- 15 1. eye safety to the highest possible degree;
2. optimum source radiation pattern distributing the power-limited optical  
signal in an efficient way to gain maximum transmission distance at  
minimum dynamic range. This is of particular interest if an optical  
20 transmitter module is used in common office environments (low ceiling,  
diffuse propagation mode).
3. no need for aligning transmitters and receivers;
- 25 4. for environments with a very high ceiling with poor (or non-existing)  
reflection properties (buildings with atrium, large lecture theatres,  
outdoors) the possibility to rely on line-of-sight (LOS) propagation  
without need for aligning the transceiver modules.

30 In connection with Figure 1, the basic concept of a transmitter module in accordance with the present invention is described. As illustrated in this Figure, such an optical transmitter module comprises an array of light emitting diodes 11, which are arranged in a regular and symmetrical

1 manner. To fix the diodes 11 in the right position, a mounting base 10 is  
employed. The array of light emitting diodes 11 is situated in a  
dome-shaped housing 12. In the present example this dome-shaped housing  
12 is a long cylindrical tube with a domed end section. This housing 12 is at  
5 least partially transparent. In addition it comprises diffuser means to  
provide for an apparent source enlargement. Diffuser means can be  
realized in different ways. The housing 12 might for example consist of a  
plastic material comprising suspended particles of high refractive index  
such that at least part of the housing serves as diffuser. In another  
10 embodiment, diffusion of the light beams emitted by the light emitting  
diodes 11 can be achieved by means of a housing 12 having a corrugated  
surface. A plexiglass housing which has been sandblasted with glass chips  
(size between 100 - 150 micron) provides a four-fold on-axis power  
reduction with half-power angle (LEDs DN305 Stanley have been used)  
15 increase from  $7.5^{\circ}$  to  $10^{\circ}$  (vertical incidence of light at the diffuser). Other  
diffuser means will be described in connection with the following  
embodiments. Depending on the roughness of the diffuser surface, or on the  
number and size of particles integrated into the diffuser housing, either a  
full diffuser or a partial diffuser can be achieved. The usage of such a full  
20 diffuser results in a Lambertian source.

Depending on the symmetry of the configuration and elevation angle of the  
light emitting diodes, the radiation angle of the diodes, the shape of said  
housing, the diffuser means, and their location in said housing with respect  
25 to each other, different radiation patterns can be obtained. In Figure 2, top  
views of three exemplary diode configurations are shown. The mounting  
base 20, on the left hand side of Figure 2, carries only three light emitting  
diodes 21 being arranged in a triangular manner. The mounting base 22,  
carries four regularly arranged diodes 23, and the mounting base 24 carries  
30 eight light emitting diodes 25. These eight diodes 25 are arranged in a  
circular manner. It is obvious from these three examples, that any kind of  
symmetrical and regular arrangement of light emitting diodes in connection

1 with an appropriate housing and diffuser is suited to obtain a high degree of eye safety and an optimum source radiation pattern.

Before further embodiments will be described, more details concerning the light emitting diodes are given. The light emitting diodes herein shown are commercially available diodes being encapsulated in a small, conventional plastic housing. Such diodes are available in plastic housings of different size, material, and with various radiation patterns and angles. Well suited are for example Stanley DN305 and DN304 light emitting diodes. It is obvious, that the present invention is not limited to the use of individual diodes, each being encapsulated in its own housing. Under certain circumstances, it might be advantageous to use an array of diodes, all of them being encapsulated or packaged in one common housing. It is further conceivable, to employ either separate light emitting diodes or an array of light emitting diodes grown on a common substrate, without housing. The dome-shaped housing in which these diodes will be located, then replaces the diode's own housing and serves to protect these diodes.

In Figure 3, another optical transmitter module, in accordance with the present invention, is shown. This module comprises a mounting base 30 on which light emitting diodes 31 are arranged in a regular and symmetrical manner. The mounting base 30 has inclined surfaces and the diodes 31 are fixed on it such that they face towards the center axis of the cylindrical housing 32. The diffuser is integrated into the housing e.g. by means of suspended particles.

In the next embodiment, illustrated in Figure 4, a computer-generated phase hologram 43 is employed to obtain suitable beam shaping. This hologram is located in the cylindrical housing 42 which covers the array of light emitting diodes 41 located on a mounting base 40.

In Figure 5, an optical transmitter module with dome-shaped housing 52 is shown. This module further comprises a mounting base 50 carrying an array

1 of light emitting diodes 51. Part of the housing 52 comprises a full diffusor  
surface 53 to obtain diffusion of the light beams emitted by the diodes 51.  
Similar results can be obtained by means of a checkerboard diffusor pattern  
applied to the housing. If the diffusor surface is situated at the inside of the  
5 housing 52, contamination of the diffusor by finger grease or dust can be  
prevented. Different degrees of diffusion may be obtained by varying the  
roughness of the diffusor surface, by changing the checkerboard pattern, or  
by applying the diffusor surface on the inside and the outside of the  
housing. The required surface roughness can be obtained by sandblasting  
10 or etching the mould for pressing the plastic housing. In case of a plastic  
housing comprising suspended particles, the degree of diffusion can be  
modified by imbedding particles of different size and/or shape.

Other dome-shaped housings 60 and 61 are schematically illustrated in  
15 Figures 6A and 6B.

The optical transmitter module given in Figure 7, comprises a flat mounting  
base 70 on which conventional light emitting diodes 71 are arranged. The  
pins of these diodes are bent, such that the diodes emit light towards the  
20 center axis 74 of the dome-shaped housing 72. This arrangement is  
advantageous in applications where the space is limited and the whole  
transmitter module ought to be small. It has been determined, that the  
inclination angle of the diodes, i.e. the angle between a plane being  
perpendicular to the center axis 74 of the dome-shaped housing 72 and the  
25 center axis 75 of the diode's radiation cone, should preferably lie between  
 $5^{\circ}$  and  $80^{\circ}$ , and in particular between  $20^{\circ}$  and  $40^{\circ}$ . The optimum angle  
between the center axis of a LED and the mounting base is about  $25^{\circ}$ , as far  
as the use in the herein described and claimed modules is concerned. The  
angle of  $25^{\circ}$  results in a maximum diffuse range in offices with low ceilings  
30 (2.5 - 3.5m).

Another configuration is illustrated in Figure 8. In this embodiment, eight  
light emitting diodes 81, each of them having its own housing, are arranged

1 In a circular and regular manner on a mounting base 80 such that light is emitted radially with respect to the module's center axis 83. Narrow-beam light emitting diodes with an elevation angle of approximately  $25^{\circ}$  are well suited for use in this embodiment.

5 A similar, star-like configuration with eight diodes is shown in Figure 9. In this embodiment, the diodes 91 carried by a mounting base 90 face towards the center axis of the housing. On the left hand side of this Figure, a housing with a full diffuser surface 93 is shown. Full diffuser means that the  
10 corrugated surface covers the whole beam cross section. The diffuser can be strong (producing a Lambertian source) or weak (producing additional scattering of the beam to improve eye-safety). This full diffuser surface is realized at the inner surface of the dome-shaped housing. The respective radiation pattern obtained by diffuser means 93 is illustrated next to it. On  
15 the right hand side, a schematic sketch of a dome-shaped housing is shown which comprises a checkerboard diffuser pattern 92 serving as diffuser. The respective radiation pattern is indicated next to this sketch. As schematically illustrated, part of the light passes the diffuser almost unobstructed, and the remaining light beams are scattered. Such a checkerboard pattern could for  
20 example be realized by drilling holes into the housing, or by using a suited mask when sandblasting it.

An optical transmitter module with dome-shaped housing 102, diffuser means 103, and an additional ring-shaped prism section being integrated in  
25 the housing 104, is illustrated in Figure 10. As illustrated by means of dashed lines, this prism ring 104 deflects part of the beam power, denoted with  $\Delta$ , (downward) in a horizontal direction. The remaining portion is emitted through the diffuser 103, directly. The prism ring 104 improves line-of-sight path communication.

30

A further embodiment of the present invention is shown in Figure 11. The module illustrated in this Figure, comprises a mounting base 110 on which an array of light emitting diodes 111 is situated. These diodes 111 are

1 inclined with respect the mounting base 110 and emit light radially. The  
dome-shaped housing 112 comprises a reflector ring 114 at the inner  
surface and diffusor means 113. This reflector ring reflects at least part of  
the beams emitted by said diodes 111 upward, before the beams pass the  
5 diffusor 113.

A cross-sectional view of another embodiment is shown in Figure 12. An  
optical module is shown in this Figure, which allows to switch the beam  
pattern, as illustrated in Figures 13A - 13C. The purpose of beam switching  
10 is either to have a radiation pattern (e.g.  $25^{\circ}$ ) giving maximum  
omnidirectional range (see Figures 13A and B), or maximum range in a  
certain direction (see Figure 13C). This switchable module comprises a  
mounting base 120 on which an array of diodes 121 is fixed. The diodes are  
located in a dome-shaped housing 122 which shows diffusor means 123,  
15 reflector means 124, upward deflecting prisms 125, and downward deflecting  
prisms 126, both with roughened surfaces. The modes of operation of this  
switchable module are described in connection with Figures 13A - 13C. In  
these Figures, top views of the module are given. As shown in Figure 13A,  
the housing 122 comprises a series of reflector means 124 and deflector  
20 prisms 125, 126 along its inner surface 130. For sake of simplicity, the  
reflector means 124 are indicated by a bold line. Switching of the beam  
pattern can be achieved in that the housing with reflectors 124 and deflector  
prisms 125, 126 can be rotated with respect to and around the center axis of  
the array of light emitting diodes 121. The deflector angles (horizontal  
25 plane) determine the desired reflected beam direction. The position of the  
arrow marker 132 (on the rotating housing 122) with respect to the (fixed)  
symbols 134 indicates the selected beam pattern. If the marker 132 points  
on the symbol "empty circle", the module emits light with an elevation angle  
 $\alpha$  of approximately  $25^{\circ}$  in all directions, i.e. in this mode of operation, the  
30 module serves as omnidirectional antenna with maximum transmission  
range and is suited for low ambient light. This position repeats every  $45^{\circ}$ .

1     Marker 132 on the symbol "full circle", see Figure 13B, indicates a beam  
elevation angle  $\alpha$  of approximately  $30^\circ$  -  $40^\circ$  for increased omnidirectional  
power density in the vicinity of the module in high ambient light  
environments. This position repeats every  $45^\circ$ . In the example shown in  
5     Figure 13C, the pointer 132 points on the symbol "arrow". This indicates the  
selected beam direction for increased directed range. The beams within the  
housing are indicated by means of dashed arrows. Eight different radiation  
directions may be chosen in increments of  $45^\circ$ .

10    In Figures 14 to 16, optical transceiver modules, in accordance with the  
present invention, are shown. The embodiment shown in Figure 14 is based  
on the module illustrated in Figure 3. This module in addition to the  
transmitter part comprises a receiver. The receiver has four photodiodes  
143 arranged below the mounting base 140. These photodiodes are tilted  
15    and face in different directions to receive light from all around the module.  
The orientation and configuration of these photodiodes depends on the  
field-of-view of each diode, as well as on the shape of the housing and the  
position within the housing. The photodiodes are protected by a thin wire  
mesh 145 which serves as Faraday cage to reduce electro magnetic  
20    interference. In the present embodiment, this wire mesh 145 is integrated  
into the dome-shaped housing 142. In this module, a substrate 144 for  
electronic circuitry in SMD-Technology is situated underneath the  
photodiodes 143. This substrate 144 might carry preamplifiers, LED drivers,  
or complete analog chips, if the space permits.

25    In the next embodiment which is shown in Figure 15, the receiver part is  
situated above the transmitter part, i.e. above the light emitting diodes  
carried by a mounting base 150. The receiver comprises an array of five  
photodiodes 153, all of them being arranged such that light is received from  
30    all directions. These photodiodes are protected by a wire mesh 155 being  
integrated into the domed endsection of the housing 152. A substrate 154  
with electronic circuitry is situated underneath these photodiodes 153. The



1 receiver part is separated from the transmitter by means of a reflector 156.  
In Figure 15B, a schematic top view of the receiver part is shown.

Another optical transceiver module is illustrated in Figure 16. This module  
5 is based on the transmitter module being shown in Figure 7 and differs in  
that a receiver is integrated in the same housing 162. This receiver  
comprises an array of photodiodes 161 being mounted on a base plate 160.  
The receiver is located such that the beams emitted by the light emitting  
10 light emitting diodes with an elevation angle of approximately  $25^{\circ}$  are well  
suited for use in this embodiment. Modules with a star-shaped array of 3 - 6  
photodiodes at  $30^{\circ}$  -  $45^{\circ}$  elevation angle showed good results.

Another embodiment of the present invention is illustrated in Figures 17 A  
15 and 17B. Shown is a cross section and top view of a module with switchable  
beam pattern. The array of light emitting diodes 201 is situated on a  
mounting base 203. The light emitting diodes 201 are located in a  
symmetrical manner underneath a dome-shaped diffuser housing 200. If this  
housing is in Position 1 (Pos. 1) with respect to the light emitting diodes 201  
20 (see right hand side of Figures 17A and 17B), the light is emitted vertically  
through the housing 200. Depending on whether this part of the housing is  
realized as diffuser, the beam pattern is focussed or spread. The housing  
200 comprises a reflector ring 202. If the housing 200 or the reflector ring  
202 is rotated with respect to the diodes 201 (Pos. 2 on the left hand side of  
25 Figures 17A and 17B) the light beams emitted by the diodes are reflected  
towards the side facet of the housing 200. This side facet is usually  
comprises diffuser means to achieve widening of the beam. It is shown in  
Figure 17B that the reflector ring 202 might be carried out as a ring with  
several 'longues'. The reflector ring 202 can be made using a thin metal  
30 which is embossed or punched. In the example given in Figures 17A and  
17B, a rotation of  $22.5^{\circ}$  allows to switch from position 1 to position 2.

1 Another concept of an optical transmitter module with switchable beam  
pattern is illustrated in Figures 18A and 18B. This module comprises an  
array of light emitting diodes 211 which are situated in via holes or  
depressions of a mounting base 213. The diodes 211 are covered by a  
5 dome-shaped diffuser housing 210. A reflector ring 212 is integrated into the  
housing 210. This ring 212 comprises tongues or cantilevers bent such that  
the light beam emitted by the diodes is reflected towards the side walls of  
the diffuser housing 210 (see position 2 on the left hand side of Figures 18A  
and 18B). If the housing with reflector ring is rotated such that the diodes  
10 211 are not situated underneath the reflecting tongues or cantilevers of the  
ring 212, the light beams are emitted vertically with respect to the mounting  
base 213 (see position 1 on the right hand side of Figures 18A and 18B).

In Figures 19A and 19B, a fixture for mounting a module 220 with switchable  
15 beam pattern is shown. In Figure 19A, the housing and reflector ring is in  
position 2, i.e. the light beam is emitted omnidirectional, and the transmitter  
radiates as indicated by the arrows. In Figure 19B, the fixture 211 with  
module 220 is opened up, and the module is in position 1, i.e. it radiates  
light perpendicular to the mounting base of the diodes. This fixture 221  
20 allows direct line of sight communication if the module is in position 1 and  
faces a remote receiver.

Another configuration of a switchable transmitter module is shown in Figure  
20. In this embodiment, the center axis of the diodes 221 are tilted  
25 approximately  $25^{\circ}$  with respect to the mounting base 223. If the  
dome-shaped housing 220 is in position 1 (see right hand side of Figure 20),  
the light beams pass the housing as indicated. In position 2, a reflector 222  
is placed in front of the light emitting diodes 221, and the light beam is  
reflected upwards (see Figure 20 on the left hand side). In the present  
30 example, the reflector 222 is a thin metal plate having an angle of inclination  
of about  $58^{\circ}$ . The reflectors can be carried by a metal ring which is  
integrated into, or fixed in the housing 220.

1 The reflector ring shown in Figures 17, 18, and 20, might be replaced by a  
prism ring. This is a ring which could be made of plastic and which carries a  
series of prism shaped and arranged such that different beam radiation  
patterns are obtained depending on the position of this prism ring with  
5 respect to the light emitting diodes. This prism ring might be an integral  
part of the dome-shaped housing. Different approaches are conceivable  
where either the housing carrying the prism or reflector ring is rotated with  
respect to the position of the diodes, or where the ring as such is rotated  
with respect to the housing and diodes, or where the diodes themselves are  
10 rotated.

The reflectors in Figures 11 and 12 might be replaced by a metal ring  
carrying 'tongues' or cantilevers, as described in connection with Figures  
17, 18 and 20. The only difference with respect to a switchable module  
15 would be that this metal ring would then be fixed (not rotatable).

Two different integration or attachment schemes of the present transmitter  
and transceiver modules for notebook computers are illustrated in Figures  
21A and 21B. The optical transmitter or transceiver modules herein  
20 described should be free of near-field obstructions through housing or  
display panel of the computer to which it is attached or into which it is  
integrated. In Figure 21A, a notebook computer 170 with removable optical  
transmitter/transceiver module 171 is shown. This module 171 is attached  
with a magnet or Velcro clip 172 to said computer 170. A cable 173  
25 interconnects the module 171 with an interface card plugged into one of the  
computer slots. In Figure 21B, a computer 174 with integrated module 175  
is shown. This module is integrated into the display and any electrical  
interconnections and the respective interface circuitry are placed inside the  
computer. This module 175 can be retractable.

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A block diagram of a specially designed analog frontend circuitry is  
illustrated in Figure 22. This circuitry comprises preamplifiers 180 coupled  
to each photodiode of the photodiode array 181 as receiver. The switches

1 182 together with a switch control unit 183 facilitate a selection of the  
signals received by the respective photodiodes. All, or a subset of the  
received signals is forwarded to a postamplifier 184, and then fed through a  
filter 185 to a comparator 186. In the present block diagram, means for  
5 proximity detection are included. For proximity detection the echo signal  
received at the photodiodes 181 and emitted by the array of light emitting  
diodes 187 is watched. If the echo signal exceeds a predetermined level, the  
light emitting diodes 187 are automatically switched off. This active safety  
interlock is achieved by means of a peak signal detector 188 which is  
10 coupled via a bus n parallel lines to the output of the preamplifiers 180. A  
control circuit 190 analyzes the received signal to detect strong echo  
signals. It then immediately switches the drivers 191 such that no more  
light is emitted. The control circuitry 190, together with a DC photo current  
detector 189 and the switch control unit 183 allows an automated selection  
15 and/or combination of signals. This selection takes into account the actual  
signal strengths and/or the DC currents (measure of shot noise received  
from directed ambient light sources like sunlight, desk lamps) of the  
photodiodes 181.

20 The whole analog frontend is connected via an interface unit 192 (PCMCIA)  
to the microprocessor bus 193.

The optical transmitter modules and transceiver modules presented herein  
are eye-safe optical systems and have several additional advantages. They  
25 are compact and suited for integration into computers and other devices. A  
module in accordance with the present invention can be easily attached to  
any notebook computer. The modules are characterized by their optimum,  
nearly uniform circular radiation characteristic, which in some embodiments  
can be switched. The modules allow to distribute and receive the  
30 power-limited optical signal in an efficient way to gain maximum  
transmission distance. Intense directed ambient light can be suppressed by  
means of an analog frontend as illustrated in Figure 18. The present  
modules are distinguished from conventional transmitters in that less total

1 shot noise occurs, thus improving the signal/noise ratio and transmission range. In addition, there is no need for aligning the transceiver modules. One special embodiment of the present invention facilitates two transmission modes namely diffuse and/or line-of-sight communication.

5 The present transmitter and transceiver modules comply with IEC 825-1 regulations. This can be achieved with a large enough extended apparent source, and/or with an active safety interlock if the head of a person comes too close to the emitter. As described above, this interlock mechanism might  
10 be based on sensing the strong reflected echo signal with the photodiodes of the emitting transceiver module caused by a nearby object (proximity detection).

The present invention provides an automatic mechanism to block intense  
15 directional ambient light (from desk lamps, windows, direct sunlight) in order to optimize the transmission range for a given data rate. This feature can be implemented by selectivity-combining of individual photodiodes pointing in different spatial directions (sectorization), thus selecting the maximum possible signal/noise ratio.

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**CLAIMS**

1. Optical data transmission module comprising an array of light emitting diodes (51) being arranged in a regular, and preferably symmetrical, manner in a dome-shaped housing (52) with diffusor means for an apparent source enlargement, said light emitting diodes being either individually or commonly addressable.
2. The module of claim 1, wherein the light emitting diodes of said array (11; 201) are located on a mounting base (10; 203) such that the main radiation axis of the diodes is approximately parallel to the center axis of said dome-shaped housing (12; 200).
3. The module of claim 1, wherein the light emitting diodes of said array (31; 41; 51; 71; 81; 91; 101; 111; 121; 221) are located on a mounting base (30; 40; 50; 70; 80; 90; 100; 110; 120; 140; 150; 223) such that the main radiation axis of the diodes is tilted with respect to the center axis of said dome-shaped housing (32; 42; 52; 60; 61; 72; 102; 112; 122; 142; 152; 162; 220).
4. The module of claim 3, wherein the light emitting diodes (31; 41; 51; 71; 91; 101) are arranged such that they face towards said center axis.
5. The module of claim 3, wherein the light emitting diodes (81; 111; 121; 221) are arranged such that they face radially outwards with respect to said center axis.
6. The module of any of the preceding claims, wherein said dome-shaped housing (42) comprises a phase hologram (43) serving as beam shaper and being located inside the housing.

- 1     7. The module of one of the claims 1-5, wherein said dome-shaped housing (52) comprises suspended particles of high refractive index which serve as diffusor means (53).
- 5     8. The module of one of the claims 1-5, wherein said dome-shaped housing comprises a corrugated surface (93) at the inner and/or outer surface which serve as diffusor means.
- 10    9. The module of claim 8, wherein said corrugated surface has a degree of roughness which matches the wavelength emitted by the light emitting diodes of the module.
- 15    10. The module of one of the claims 1-5, wherein said dome-shaped housing comprises a checkerboard pattern (92) at the inner and/or outer surface which serve as diffusor means.
- 20    11. The module of any of the preceding claims, wherein said dome-shaped housing (102) comprises a prism ring (104) which reflects part of the light ( $\Delta$ ) emitted by said array of light emitting diodes (101) downwards such that direct line-of-sight communication is improved.
- 25    12. The module of one of the claims 1-10, wherein said dome-shaped housing (112) comprises reflectors (114) located at the inner surface of the housing (112) which reflect the light emitted by said array of light emitting diodes (111) upwards such that it leaves the housing (112) through said diffusor means (113).
- 30    13. The module of one of the claims 1-10, wherein said dome-shaped housing (122) comprises a series of reflectors (124), upward facing deflector prisms (125), and downward facing deflector prism (126) located in a circular manner at the inner surface of the housing (122), such that, depending on the position of said array of light emitting

- 1 diodes (121) with respect to said reflectors (124) and prisms (125, 126),  
the radiation pattern of said module can be switched.
14. The module of one of the claims 1-10, wherein said dome-shaped  
5 housing (200; 210; 220) comprises a series of reflectors (202; 212; 222),  
or a series of prisms located in a circular manner in said dome-shaped  
housing (200; 210; 220) such that, depending on the position of said  
array of light emitting diodes (201; 211; 221) with respect to said  
reflectors (202; 212; 222) or prisms, the radiation pattern of said module  
10 can be switched.
15. The module of one of the claims 13 or 14, wherein said dome-shaped  
housing (122; 200; 210; 220) is stepwise rotatable with respect to said  
array of light emitting diodes (121; 201; 211; 221).
- 15 16. The module of any of the preceding claims, further comprising a  
receiver with an array of photodiodes (143; 153; 161) being tilted with  
respect to said center axis of the housing.
- 20 17. The module of claim 16, wherein said photodiodes (143) are located  
below said array of light emitting diodes in the same housing (142).
18. The module of claim 16, wherein said photodiodes (153; 161) are located  
above said array of light emitting diodes in the same housing (152; 162).
- 25 19. The module of one of the claims 16-18, wherein said photodiodes (143;  
153; 161) are mounted on a mounting base (160) which is fixed in said  
housing (142; 152; 162).
- 30 20. The module of claim 16, wherein said housing (142; 152) comprises a  
substrate (144; 154) with electronic circuitry and or a thin wire mesh  
(145; 155).



- 1     21. Computer (170; 174) comprising an optical transmitter module (171; 175)  
according to any of the preceding claims, and interface means for  
coupling said module (171; 175) to the bus of said computer.
- 5     22. The computer of claim 21, wherein said module (171) is attached to the  
display panel of the computer by means of a clip (172) and connected to  
said interface means via a cable (173).
- 10     23. The computer of claim 21, wherein said module (175) is integrated in  
fixed or retractable manner into the display panel of the computer.
- 15     24. Optical transceiver for wireless data communication comprising  
a) an array of photodiodes (181),  
b) amplifiers (180, 184) for amplification of the signals received by said  
array of photodiodes (181),  
c) means (186) for detecting the information carried in the signals  
received by said array of photodiodes (181),  
d) an array of light emitting diodes (187),  
e) driver means (191) for driving the diodes of said array of light  
20     emitting diodes (187),  
f) means (182 183, 190) for active selection and individual combination  
of the signals received by each of the photodiodes of said array of  
photodiodes (181),  
g) means (188 - 191) for proximity detection which determine the  
25     strength of the echo signal and switch of the light emitting diodes of  
said array of light emitting diodes (187) if said echo signal exceeds  
a predefined limit.
- 30     25. The optical transceiver of claim 24 being coupled via interface means  
(192) to the bus (193) of a computer.

## AMENDED CLAIMS

[received by the International Bureau on 19 July 1995 (19.07.95);  
original claims 24 and 25 cancelled; original claim 1 amended; new  
claims 24-27 added; remaining claims unchanged (5 pages)]

1. Optical data transmission module comprising an array of infra-red light  
emitting diodes (51) being arranged in a regular, and preferably  
symmetrical, manner in the cavity formed by a dome-shaped  
housing (52) with diffuser means such that
- infra-red light is emitted from said array through said  
dome-shaped housing (52),
  - said diffuser means provide for an apparent source enlargement,  
and
  - said light emitting diodes are either individually or commonly  
addressable.

New claim 24

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24. Transceiver for wireless data communication and for use in connection with a module of claim 1 - 15, comprising

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- a) an array of photodiodes (181),
- b) amplifiers (180, 184) for amplification of the signals received by said array of photodiodes,
- c) means (186) for detecting the information carried in the signals received by said array of photodiodes (181),
- d) driver means (191) for driving the array of infra-red light emitting diodes of said module,
- e) means (182 183, 190) for active selection and individual combination of the signals received by each of the photodiodes of said array of photodiodes (181),
- f) means (188 - 191) for proximity detection by determining the strength of an echo signal and switching off the array of infra-red light emitting diodes of said module if said echo signal exceeds a predefined limit.

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New claim 25

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25. Transceiver for wireless data communication and for use in connection with a module of claim 16-19, comprising

- a) amplifiers (180, 184) for amplification of the signals received by the array of photodiodes of said module,
- 10 b) means (186) for detecting the information carried in the signals received by the array of photodiodes of said module,
- c) driver means (191) for driving the array of infra-red light emitting diodes of said module,
- d) means (182 183, 190) for active selection and individual combination  
15 of the signals received by each of the photodiodes of the array of photodiodes of said module,
- e) means (188 - 191) for proximity detection by determining the strength of an echo signal and switching off the array of infra-red light emitting diodes of said module if said echo signal exceeds a  
20 predefined limit.

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New claim 26

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26. The optical transceiver of claim 24 being connected to any of the modules of claims 1-15 and being coupled via interface means (192) to the bus (193) of a computer.

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New claim 27

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27. The optical transceiver of claim 25 being connected to any of the modules of claims 16-19 and being coupled via interface means (192) to the bus (193) of a computer.

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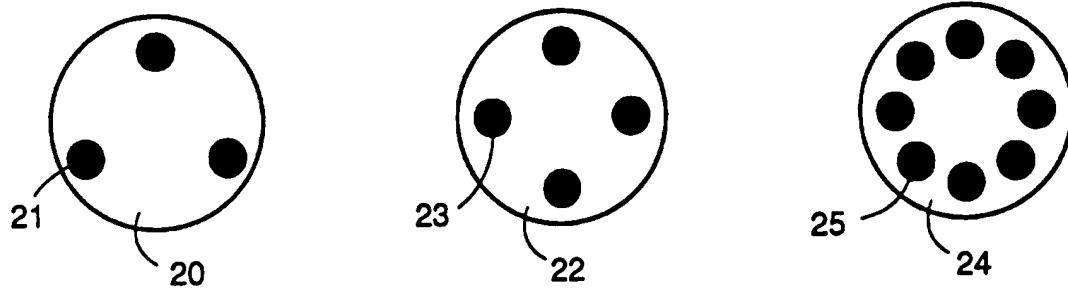
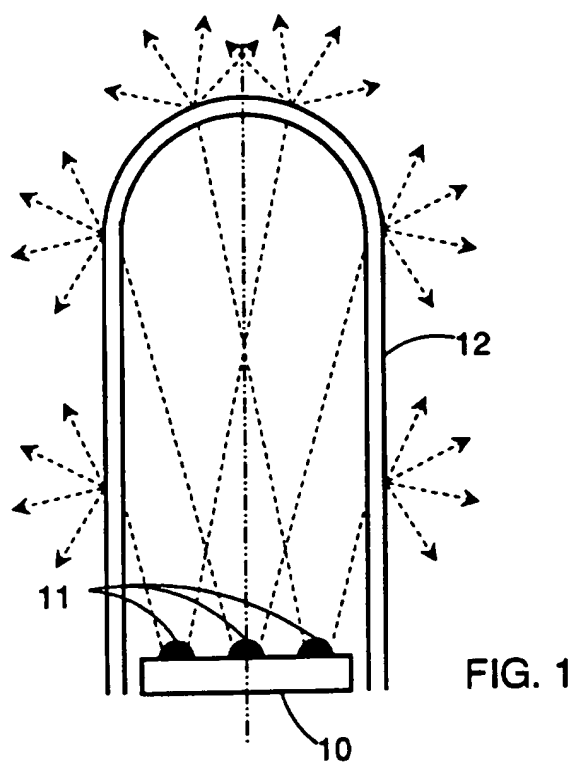
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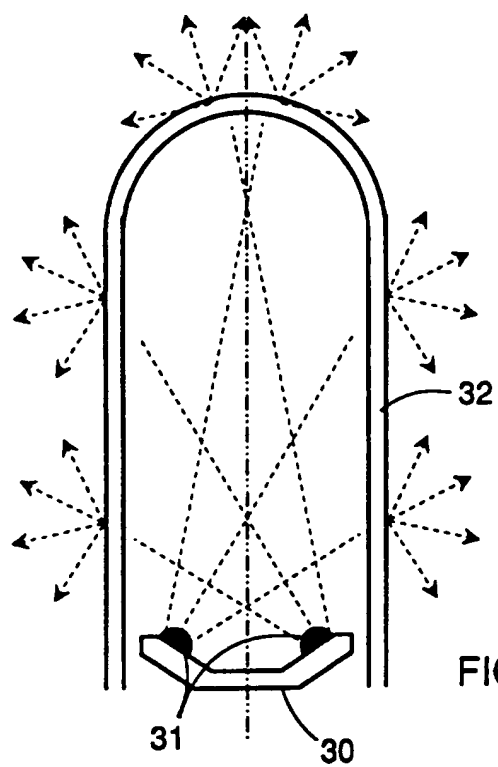


FIG. 3

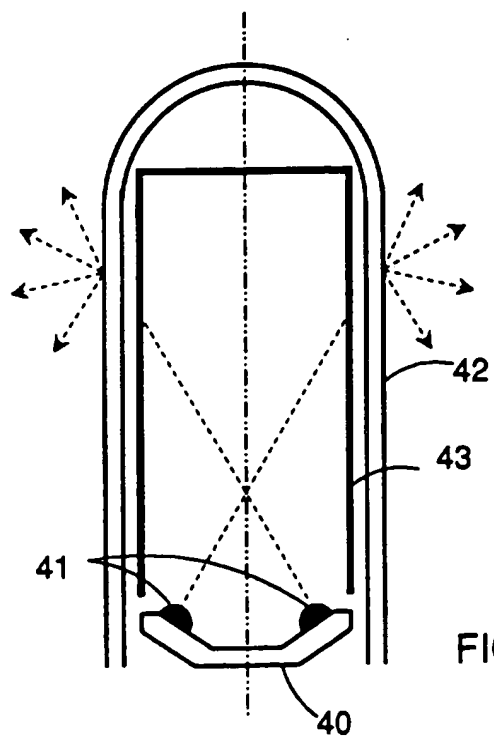


FIG. 4



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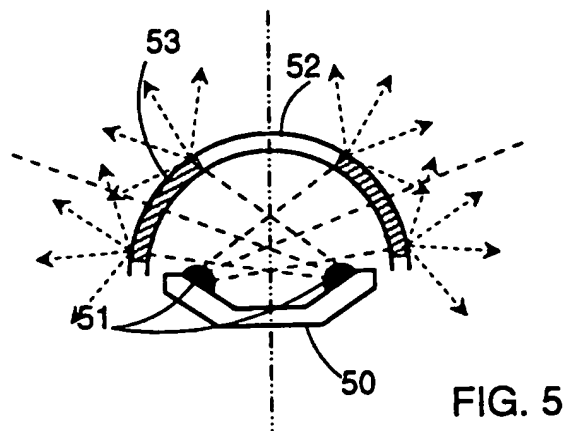


FIG. 5

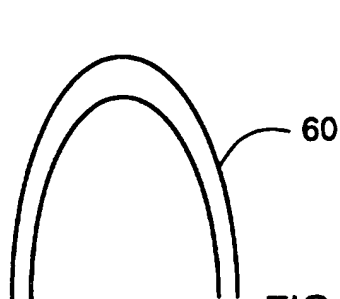


FIG. 6A



FIG. 6B

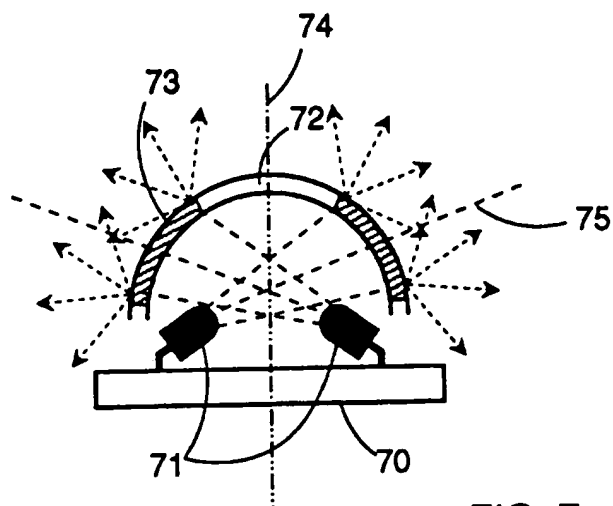


FIG. 7

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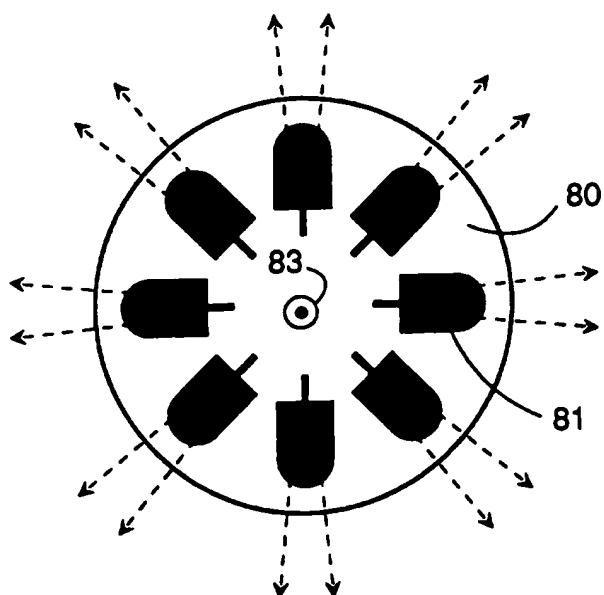


FIG. 8

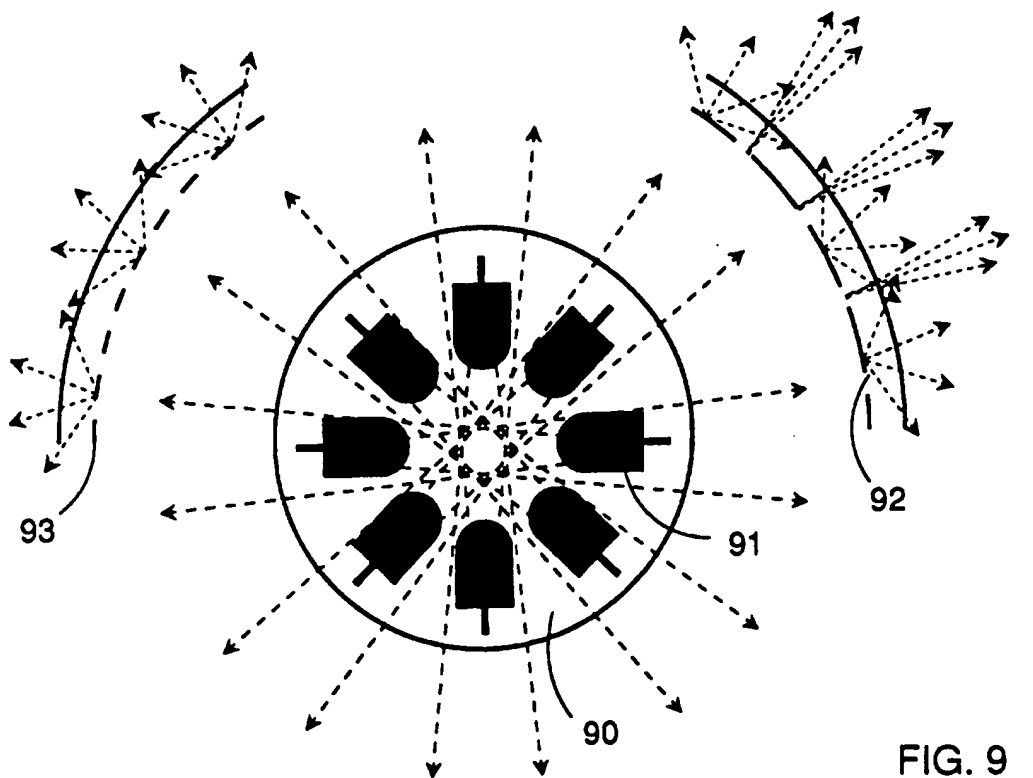


FIG. 9

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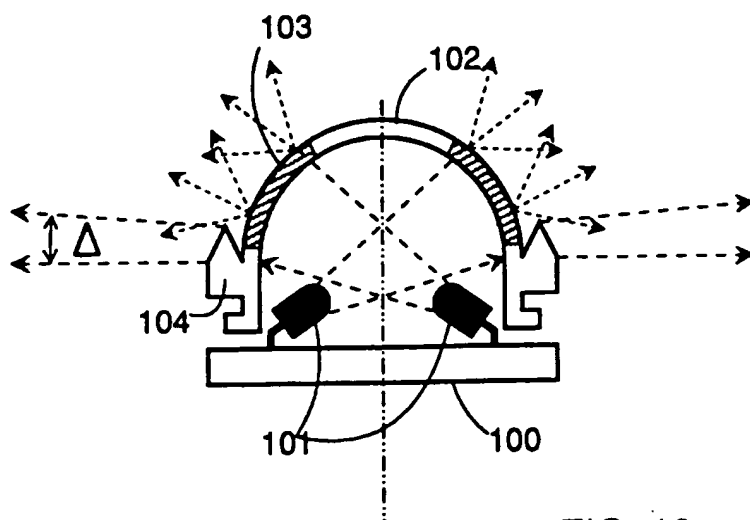


FIG. 10

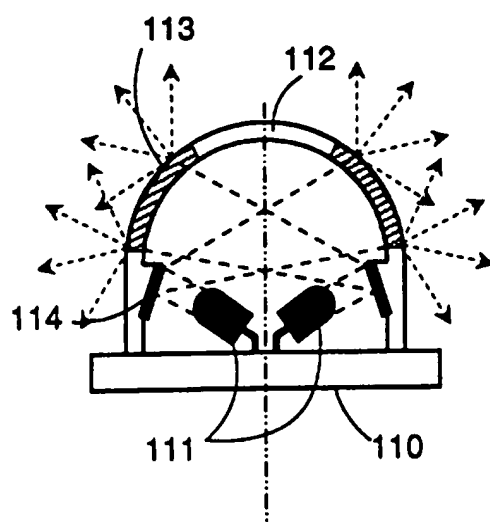


FIG. 11

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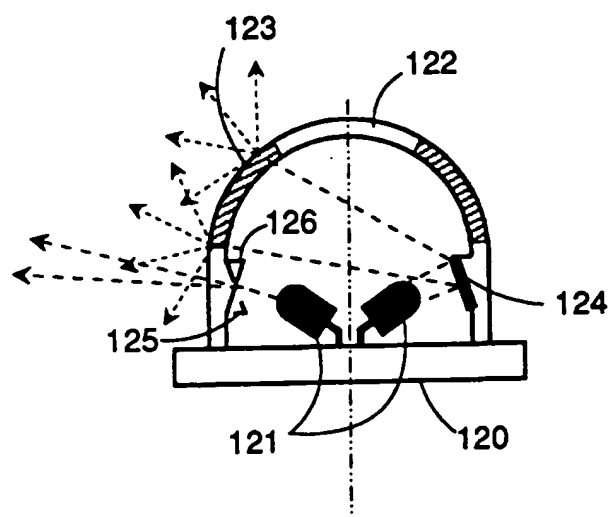


FIG. 12

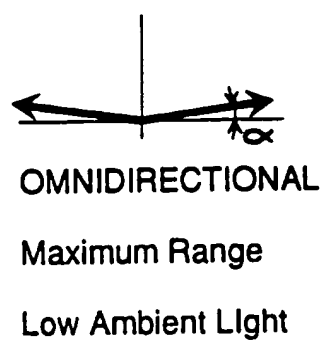
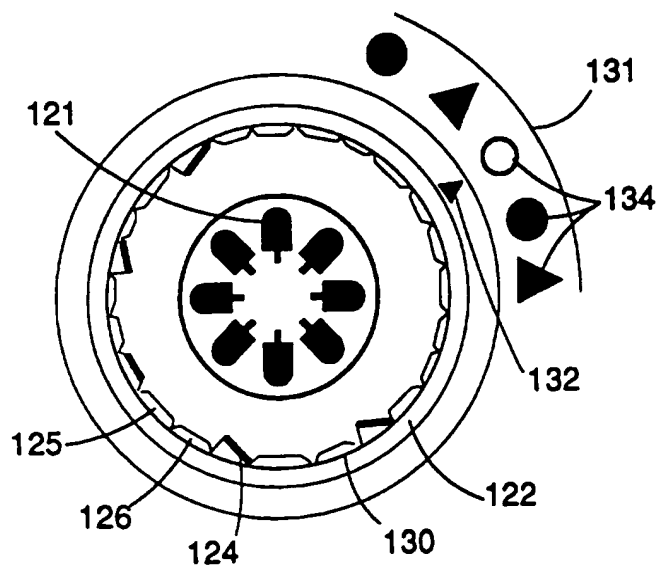
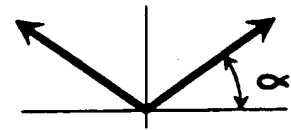
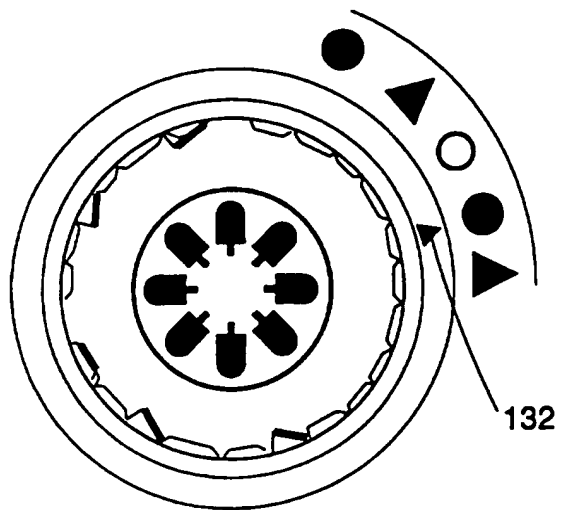


FIG. 13A

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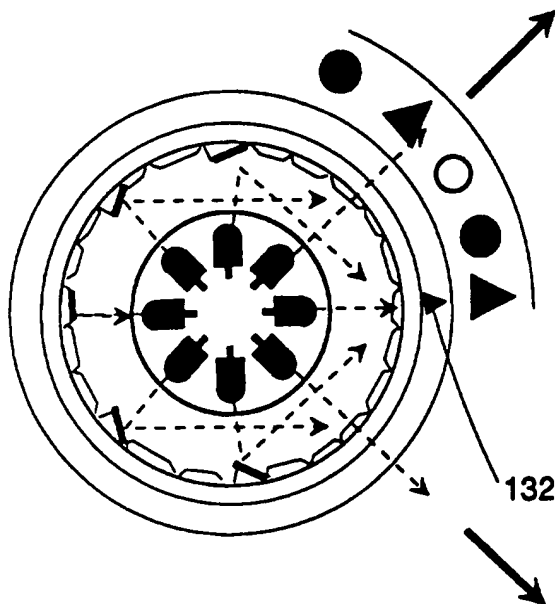


OMNIDIRECTIONAL

Reduced Range

High Ambient Light

FIG. 13B



DIRECTIONAL

Maximum Range

in one Direction

FIG. 13C

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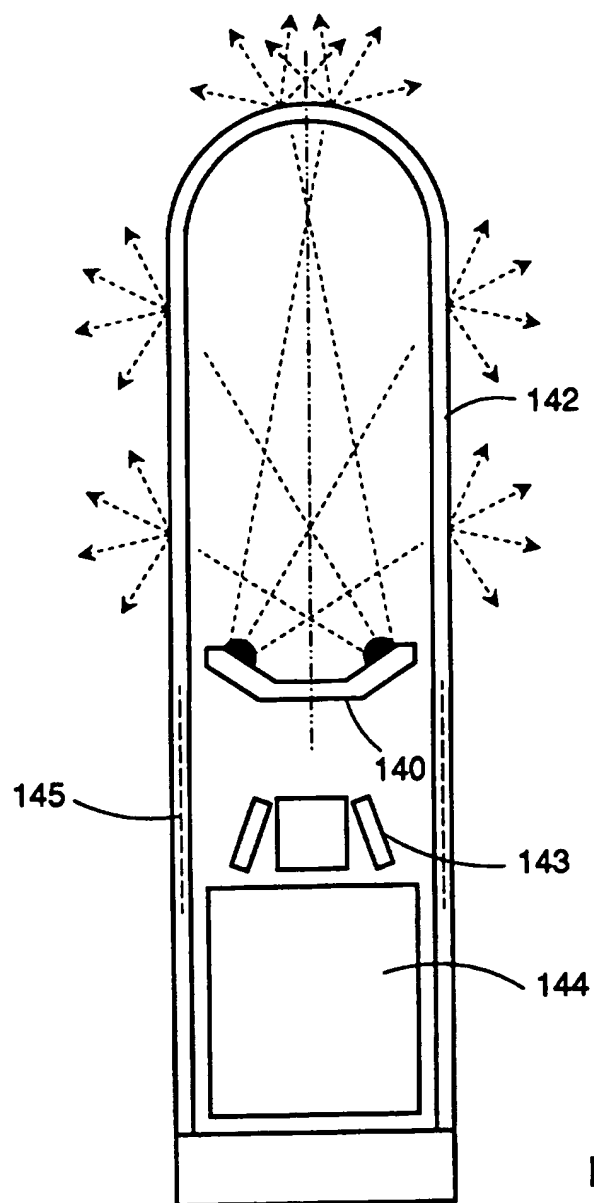
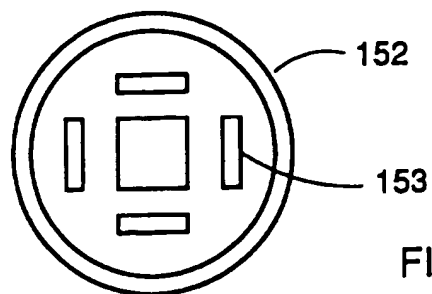
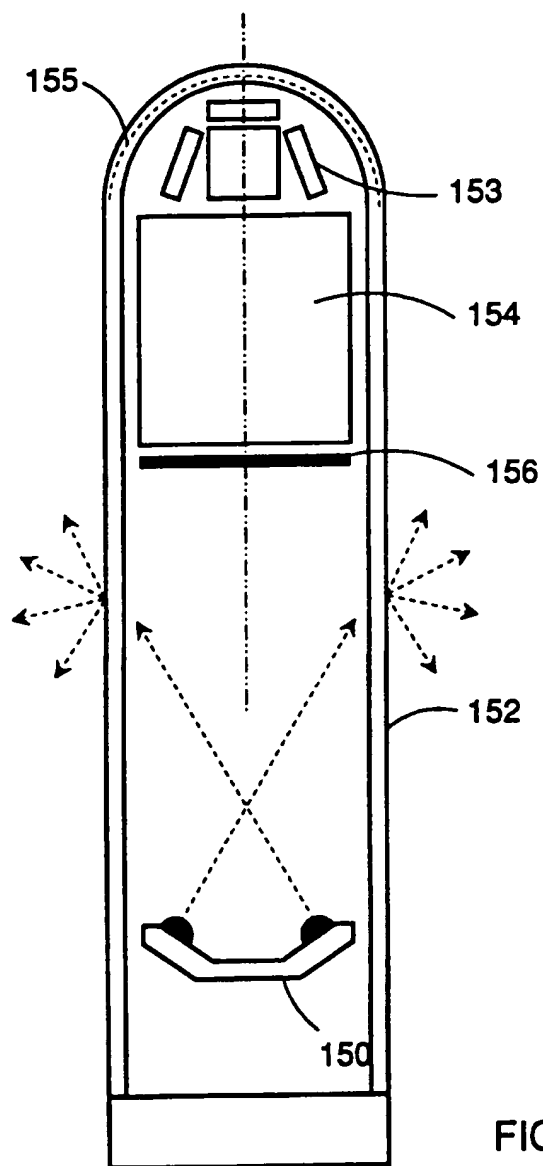


FIG. 14

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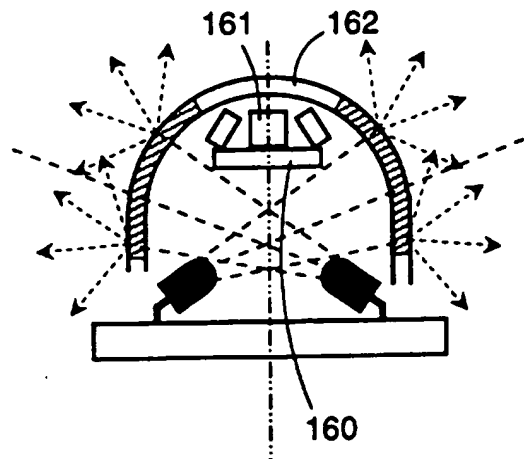


FIG. 16

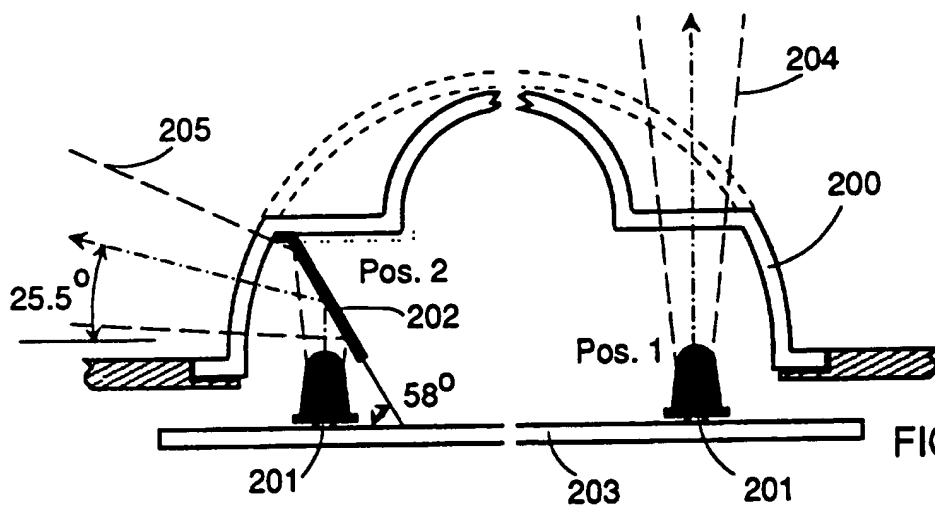


FIG. 17A

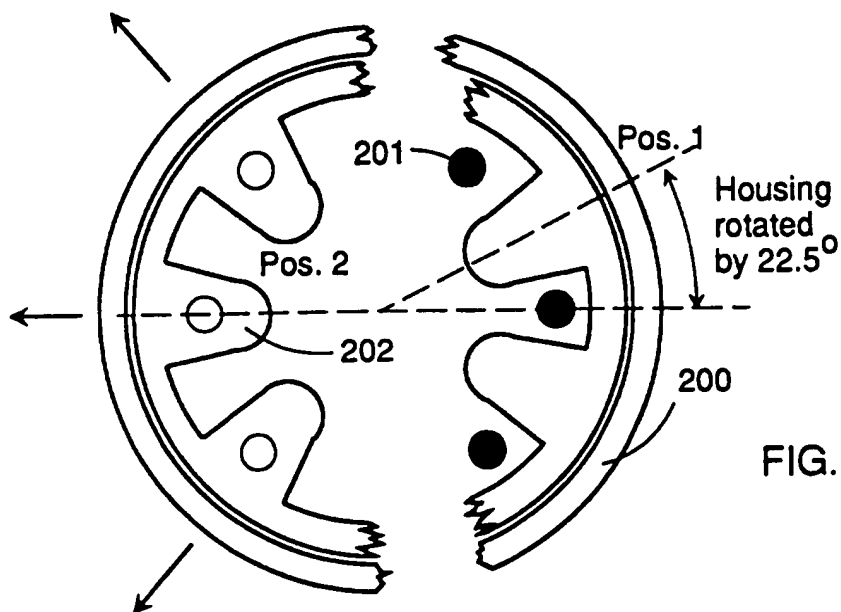
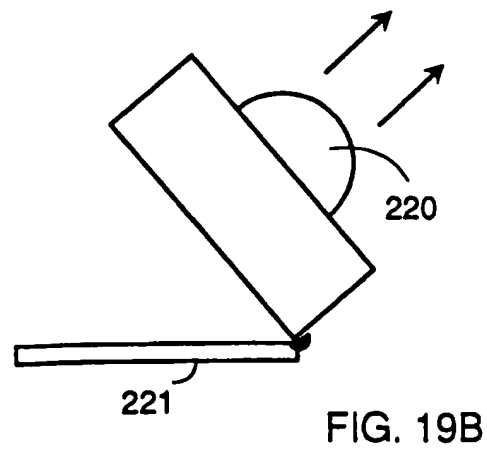
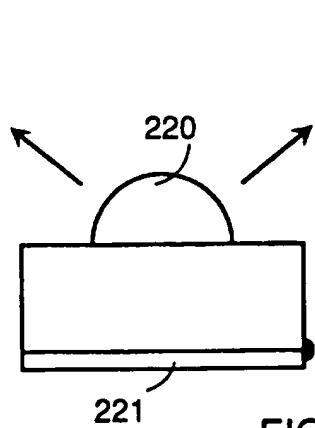
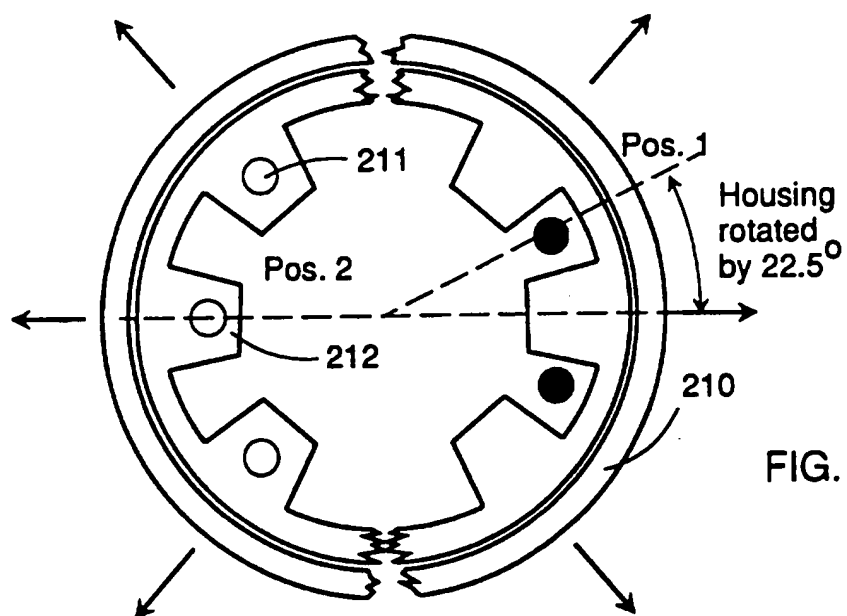
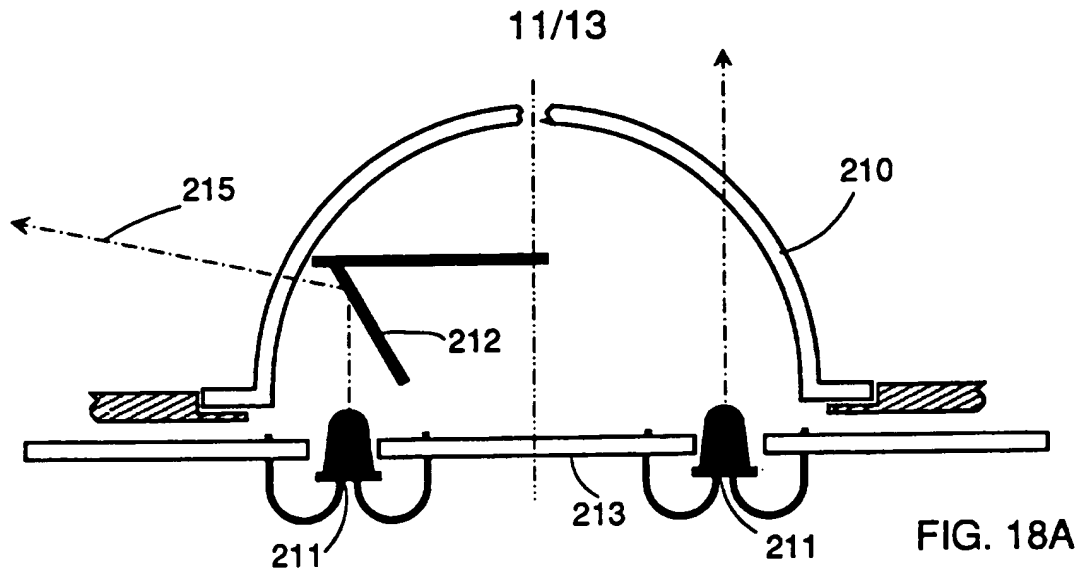
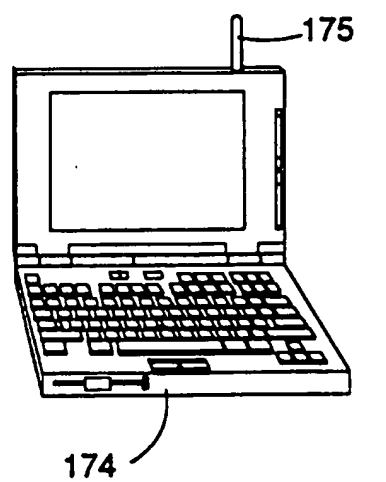
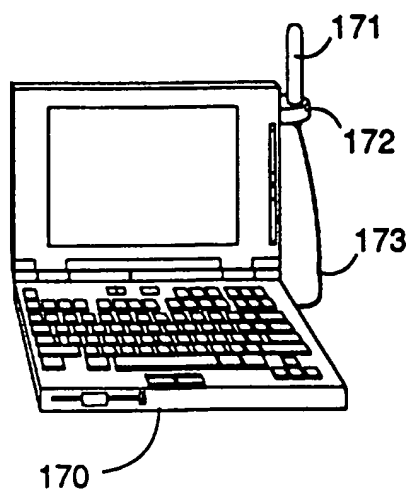
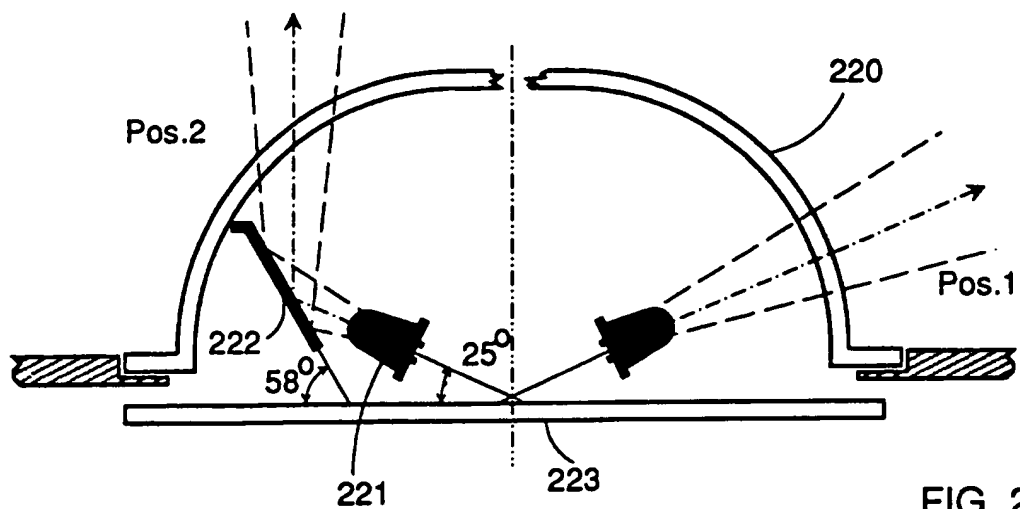


FIG. 17B





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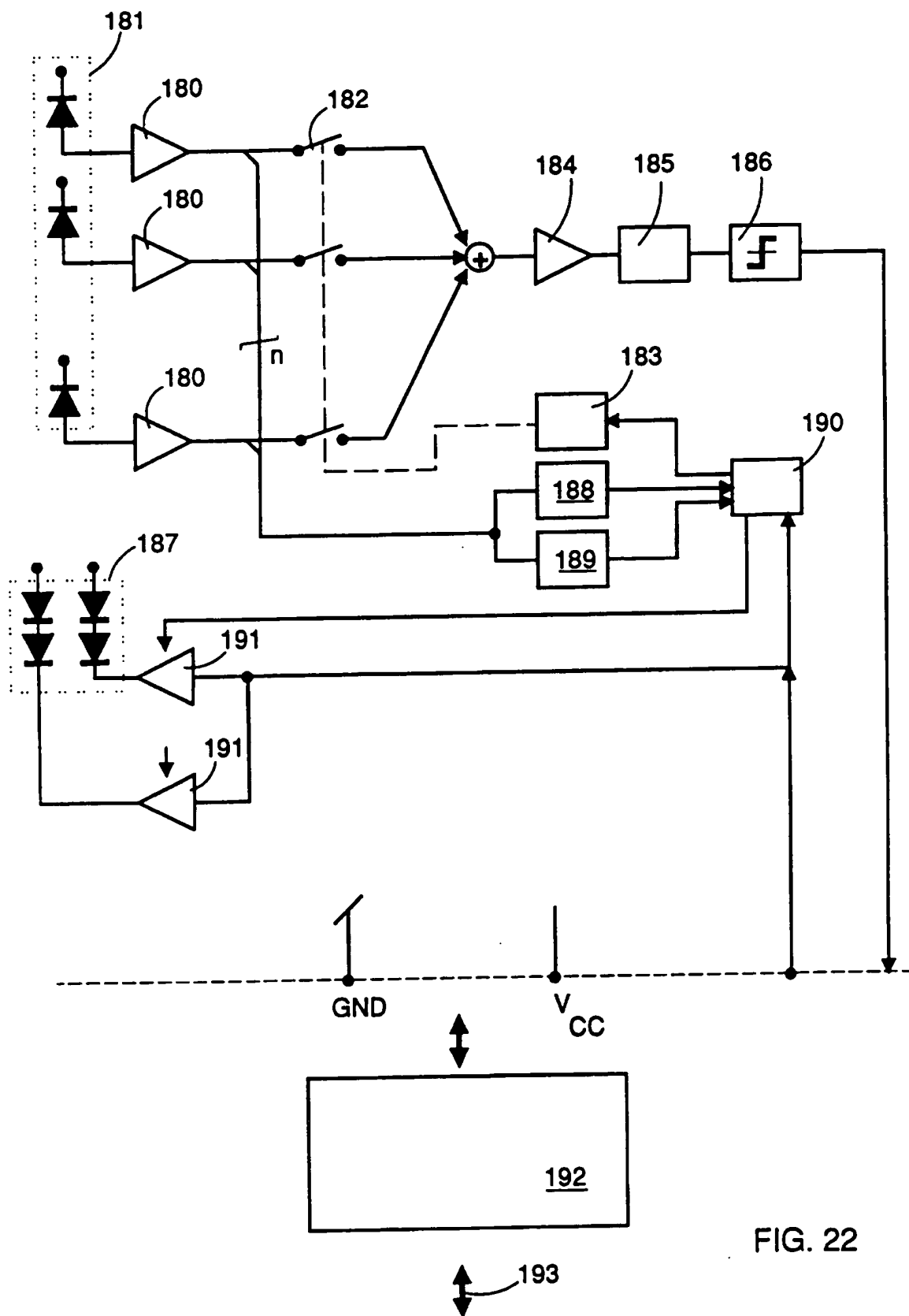


FIG. 22

# INTERNATIONAL SEARCH REPORT

Intern. Appl. Application No

PCT/EP 94/02940

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 H04B10/10

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,5 258 867 (IGGULDEN ET AL) 2 November 1993	1,3,5,14
A	see abstract; figures 6-16	16
X	WO,A,90 03072 (WILMOTH) 22 March 1990	1,2
A	see page 1, line 30 - page 2, line 5; figures 3,5-12 see page 2, line 17 - line 24	16-19, 21,22
X	PATENT ABSTRACTS OF JAPAN vol. 11, no. 7 (E-469) (2454) 9 January 1987	1,2
A	& JP,A,61 182 338 (HITACHI) see abstract	6,7,12
	--- -/--	



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

24 April 1995

Date of mailing of the international search report

06.07.95

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
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Authorized officer

GOUDELIS M.

# INTERNATIONAL SEARCH REPORT

Intern. Application No

PCT/EP 94/02940

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 10, no. 108 (E-398) (2165) 23 April 1986 & JP,A,60 246 136 (CANON)	1,2
A	see abstract ---	6,7,12
A	PATENT ABSTRACTS OF JAPAN vol. 12, no. 174 (E-612) (3021) 24 May 1988 & JP,A,62 281 623 (YAGI ANTENNA CO) see abstract ---	1,2,5
A	US,A,4 727 600 (AVAKIAN) 23 February 1988  see column 2, line 40 - column 3, line 33; figures 1,3,5,6,11,12 -----	1-3,5, 16,21

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/EP 94/ 02940

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. claims 1-23: Optical transceiver module arrangement
2. claims 24,25: Electronic driving of the emitters

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-23

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

**INTERNATIONAL SEARCH REPORT**

information on patent family members

Intern. Application No

**PCT/EP 94/02940**

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